UNIVERSITY OF CALIFORNIA

LAWRENCE RADIATION LABORATORY
P.O. BOX 808
LIVERMORE, CALIFORNIA 94550

TELEPHONE (415) 447-1100
TELEX 34-6407 AEC LRL LVMR
TWX 910-386-8339 AEC LRL LVMR

19 December 1969

The Honorable Mike Gravel
United States Senate
Washington, D.C. 20510

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Dear Senator Gravel:

Your letter has been handed to me in the hospital as the first piece of correspondence I received when I was permitted to see my secretary after an operation. As you will expect, questions of health are always of particularly great interest under such conditions. At the same time, the fact that I am recovering slowly has made it entirely impossible for me to answer promptly and in a meaningful way the numerous questions which were included in the letter.

Even now it is not possible for me to provide conclusive answers to all questions. Because of the urgency which your letter indicates, it is necessary for me to concentrate on those questions where I have an answer, or at least a partial answer. As you know, I am not a radiobiologist. As you further know, the best experts in the field are in disagreement on many important points. You undoubtedly are aware of the fact that this disagreement is in part due to emotional factors.

I should also remind you of my close connection with the development of atomic energy, which covers the last three decades. This has made it necessary for me to be aware of the effects of radioactivity on health. In 1958 Dr. Albert Latter and I published a book on the subject under the title Our Nuclear Future. This book is, unfortunately, out of print. Therefore, I cannot send you a copy. I am sure that your staff will find it possible to obtain a copy.

Furthermore, I have been doing work for Governor Nelson Rockefeller in connection with air and water pollution for the past few years. Therefore, I did worry about the broader aspects of the pollution problem.

The breadth of the subject, the diversity of your questions and the nature of the testimony which was presented at your hearings, make it necessary for me to answer at some length. Because of this very fact I want to summarize my conclusions.

As you rightly say, it is difficult to balance the benefits and the dangers of atomic energy.

You also say that every single release of radioactivity constitutes some hazard to health. This opinion is widely held but it is not proven in a rigorous manner. What is clear is that the quantities of radiation considered in the radiation guide are so small as to make judgements concerning the effects of these radiations quite difficult.

One point of view that recommends itself to common sense is to compare the effects of radiation with the effects of natural exposure. This point of view has guided me throughout all the years in which I had to pay thorough attention to this difficult problem.

In order to present an instructive contrast I am including a copy of testimony prepared by Gofman and Tamplin to your committee, and a letter from John Storer to John Totter. All of these men work for the Atomic Energy Commission. The sharp difference between these two documents illustrates the fact that the Atomic Energy Commission encourages the expression of every point of view for which some support can be presented.

In connection with all of your 19 questions, I have some remarks; in several cases I have answers. These are included with my letter. In the case of Plowshare, I know of better authority in Livermore to give you an answer. This additional answer will be sent to your office.

Caution should be exercised before stringent limits are placed on man-made radiation which are less than the actual radiation to which we are exposed due to natural sources. My thoughts on this matter are sent as a separate inclusion, entitled "What Shall Be Done About the "Maximum Permissible Dose"? It is possible that after some further consideration and modification, I may publish the last mentioned document.

In connection with your question No. 14, I am including a report by Tamplin, et al. which points out some mistakes committed by Sternglass in his much-discussed paper.

In connection with the whole complex field with which we are dealing, I should like to point out that the Joint Committee on Atomic Energy has built up a tradition for handling questions connected with Atomic Energy in a most careful manner. Their work includes evaluation and proper limitation on hazards. I hope that any future legislation will be built on this excellent record.

Your request for assistance in this important matter is a great honor which I fully appreciate. I hope that you will give me a continuing opportunity to clarify points which lie in my field of competence.

Sincerely yours,

Edward Teller

Edward Teller

ET:oc
Enclosures
cc: R. Finch
C. Holifield
C. Hosmer
H. Jackson
J. Lawrence
M. May
J. Gofman
N. Rockefeller
Southern Interstate Nuclear Board
G. Seaborg
J. Kelly
T. Thompson

Answers to questions from the office of Senator Gravel.

1) The primary responsibility of the Atomic Energy Commission in connection with radioactivity is to protect health and safety of people. One way of doing this is to make sure that activities stated in the radiation guide are not exceeded. Concerning the question whether the origin of various radioactive discharges is adequately listed, I can say that on the numerous occasions when I had reason to ask questions of this kind I obtained prompt and reliable answers. In fact, I did have reason to ask questions concerning radioactivities of various half lifes, initial locations, various sources and various nuclides, in connection with my work on safeguarding reactors, on controlling radioactive fallout from tests, and on monitoring the results of exploratory explosions connected with Plowshare.

Detailed data may be obtained from the AEC Division of Compliance and Division of Reactor Safety. In addition, in many states the Public Health Service is also keeping track of these activities. These are published and readily available from Health, Education and Welfare's Radiological Health Data and Reports.

There is also some information available about radioactivities released in other countries. In the course of time this source of radioactivity will assume an increasing influence, particularly in view of the fact that in many cases these activities are effectively distributed around the globe.

The question where the various kinds of radioactivities wind up is of an even greater importance. These studies have to be carried out separately for each of the radioactive nuclides. The study of this extremely difficult problem is being carried out at a number of places, among others at the Livermore Branch of the Lawrence Radiation Laboratory. One should realize that a thorough job in this respect is both expensive and necessary.

2) Statistical studies on body-burdens and exposures have been performed by the United States Public Health Service and the Atomic Energy Commission. Some relevant data are presented in the Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. (Twenty-first Session of the United Nations, 1966.)

There is one query under item 2 which deserves special attention: "Is better understanding of low-dose radiation effects presently hampered by an insufficiency of historical data, or is sufficient data available to the scientific community?"

The study of the distribution and the effects of low-dose radiation is exceedingly difficult and a better understanding would indeed be most helpful. What I have in mind is the fact that in some regions of the world the background radiation is unusually high. This is particularly the case in the regions where thorium-containing Monazite sands occur. Outstanding examples are to be found

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in some places in Brazil and in the Province of Kerala, in India. In these regions limits of radiation given by our Federal Radiation Council Guideline are exceeded by a factor 10. Many thousands of inhabitants of Brazil and India have been exposed for generations to this relatively intense radiation. Yet only superficial studies of the effects of this radiation have been undertaken. Detailed and scientific studies could resolve some of the questions which are now debated and which have a decisive influence on the problems which your subcommittee is investigating.

A somewhat similar situation prevails over some areas of the United States. For instance, in a big fraction of the state of Colorado the background due to cosmic rays is more intensive due to the higher elevation and additional background radiation is produced by greater concentrations of uranium in the soil. The total effect is generally somewhat less than the limit prescribed by the Federal Radiation Council Guideline, but much greater than the low limit of .017 r/yr recently recommended to your committee by Gofman and Tamplin. Due to the low level of additional radiation prevailing in Colorado, such a study would admittedly have to include great numbers of people and would be difficult to carry out.

3) The general answer concerning body-burden for 1968 is available in the publication of Health, Education and Welfare, who publish on a monthly basis radioactivity contents in the diet, water, air, and in some human organs, particularly in bone. Incidentally, this publication has data not only about the U.S., but about Canada and Latin America as well.

The answer to the question whether the public is accurately enough informed on these points depends on the point of view of the questioner. If one assumes that the most pessimistic statements concerning radiation hazards are valid, the public information is certainly not sufficient.

If, on the other hand, these pessimistic views are correctly designated as expressions of an alarmist attitude, then one should argue that the present information suffices. It appears to me that danger from radioactivity is very much lower than danger from smog, sulphur dioxide and water pollution.

It is of the greatest importance to emphasize the really dangerous elements in the pollution situation and according to my judgement, the danger of radioactivity is not one of those critical dangers which deserves detailed public exposure.

4) To the extent that monitoring is a simple and straightforward procedure, present methods of monitoring do suffice. On the other hand, the real danger is connected with the possibility that the distribution of radioactivity is not uniform and that

great concentrations may occur. The way to look for these concentrations is to consider carefully the reasons which could bring about such concentrations. The most obvious reason is concentration in food chains (which indeed is the explanation of the greater concentration of cesium in the Eskimo population). As I have mentioned, these food chains are being considered carefully. I have also stated that more work along these lines is badly needed.

As far as I can find out the Beta activities fluctuate both in America and in Canada. I cannot give a convincing explanation of the fluctuations or of the recently observed ratios. It is not impossible that these contaminations may be due to nuclear atmospheric tests carried out by other countries, for instance, by China. Such tests do give rise to activities which can be held in the upper atmosphere for considerable periods of time and can then be brought down in a more or less localized fashion.

5) One curie of radioactive substance absorbed in a man is generally dangerous. It can be deadly. The result depends on the questions whether and how the radioactive material is concentrated in the human organism and what the life time and decay characteristics of the radioactivity happen to be. These questions have been under careful and continuous consideration from the very beginning of the Atomic Energy project.

6) It is accurate to say that ounce for ounce and gram for gram, radioactive substances <u>can</u> be a million times more harmful to life than common environmental pollutants. This statement carries a very considerable emotional impact. It has, however, little to do with relevant facts which describe the effects of radioactive contaminants.

One of these facts is that radioactive pollutants are being controlled in a much more effective way than other environmental pollutants and that actually, radioactive pollutants are being kept to a level whose effects in general are small compared to the effects of natural background.

A further relevant fact is that radioactivity due to radioactive contaminants do not show the capricious effects of chemical agents. What I mean is that a certain amount of energy delivered in the form of high energy radiation to a living cell will have not identical, but nevertheless similar effects, not strongly dependent on the question whether the radiation is delivered by cosmic rays or by any form of radioactivity. By contrast, the effects of a chemical poison cannot always be predicted on the basis of the chemical structure of the poison. Careful experiments have to be carried out from case to case and surprises, such as those recently presented by the cyclamates, will occur.

The most important fact is, however, that radioactivity can be easily noticed and that small amounts of radiation can be detected without difficulty, even when the amount is small compared to the amount that may become harmful. Thus the control of radioactivity is very much easier than the control of chemical contaminants. Similarly, research concerning the important question how radioactivity gets concentrated, can be carried out with greater effectiveness than similar research in the chemical field.

I have mentioned that research on the concentration of radioactivity in living organisms constitutes a very extensive program. Techniques to find these concentrations have improved and additional research will, therefore, be most fruitful. Any similar research carried out with a chemical agent would present much greater difficulties.

Therefore, we are better informed and will probably remain better informed concerning radioactive hazards than concerning the older and more common chemical hazards.

7) One thing that is certain about low doses of radi tion is that these low doses have small effects. The effects are hard to discover. I have no specific information on the effects of radiation at the exceedingly low doses which correspond to "permissible levels" on animals or plants.

One relevant fact that has received practically no publicity outside of strictly technical circles is concerned with doses of intermediate size (between 0.1 and 2 rads per day) on rats and mice. Experiments have been carried out by Carlson, Lorenz and others.* These experiments have shown that under some special conditions these doses increase the life expectancy of the small animals to an extent which is outside the statistical uncertainty. It is a widespread belief among biologists that all radiation is harmful. It is remarkable that this contrary evidence is not quoted; nor is it to my knowledge disproved in a conclusive manner.

Concerning heavy doses a lot of evidence does exist. Many microorganisms are much more resistant to radiation than man. Insects also tolerate greater doses than

*R. E. Zirkle, "Biological Effects of External X ray and Gamma Radiation", Part I, pages 24-148, 1954.
L.D. Carlson, W. J. Scheyer and B. H. Jackson, Radiation Research, Vol. 7, page 190, 1957.
L. D. Carlson and B. H. Jackson, Radiation Research, Vol. 11, Page 509, 1959.
G. A. Sacher and D. Grahn, "Journal of the National Cancer Institute, Vol. 32, 277, 19
L.K. Bustad and N. M. Gates, et al. Radiation Research, Vol. 25, page 318, 1965.

we do. There are some ani[illegible]s where the semi-lethal dose [illegible] approximately one-half the dosage for man. I do not know of any evidence among animals or plants for even greater sensitivity to radiation.

The fact that our Federal Radiation Council Guideline specifies doses equal to the average radiation background implies an assurance that no serious damage will be created in the animal and vegetable kingdom. The only justifiable worry is connected with the possible enrichment of radioactivity in food chains. As stated, there has been some work done on this question, however, I believe this field has not as yet received sufficient attention.

It is clear from the above statements that no additional controls need be recommended at present to safeguard animals and plants.

8) Due to the great dilution of tritium in the Mississippi River and in the Gulf of Mexico, no effects should be expected due to the amounts of tritium which are at present discharged.

The discharge is due to past nuclear testing. In the absence of further testing this discharge is not expected to increase.

9) It is useful to compare the rehabilitation of Bikini Island with the dire predictions because these dire predictions were unwarranted exaggerations. Some of the present dire predictions are even less warranted.

The details of the history of the radioactivity on Eniwetok and Bikini might be obtained from the Laboratory of Radiation Biology at the University of Washington, in Seattle.

10) The articles in the New York Times and Time magazine on the connection between the starfish plague and fallout seem to be based on speculation. There are many factors which can upset the ecological equilibrium. The low existing levels of fallout appear to be a rather improbable cause for a perturbation of the equilibrium.

If there is any good information on this point it may be obtained from one of the oceanographic laboratories.

11) If I or a member of my family would carry a body-burden of radionuclides similar to that characteristic of the Eskimo, I would not worry.

The body-burden of the Eskimos is probably due to Russian tests. As far as I know the situation connected with the Eskimos was first explored in detail due to the plans of a possible Plowshare explosion in Alaska. When I was Director of the Livermore Branch of the Lawrence Radiation Laboratory in 1958-60, such an explosion was in prospect. As part of the planning of this explosion, extensive research was carried out on possible food chains which could occur under the special conditions of Alaska. The amount of money spent on these studies was approximately four million dollars. As a result, progress has been made on elucidating the relevant food chains and also on proper statistics of body-burdens among Eskimos. The work is now carried on by the Battelle Northwest Laboratory at Hanford, Washington

The suggestion contained in your question No. 11 that studies be made of the Eskimo population connecting their unusual body-burden with some defects, is one which in principle appears to be highly reasonable. However, this body-burden is so low that a statistical investigation along these lines appears to be most difficult. This is particularly true because of the small numbers and the special conditions of Eskimos. This makes statistical comparisons difficult. Investigation along these lines could be more highly recommended for regions of high natural background where a larger population makes statistical comparisons somewhat more feasible.

12) Expert opinion on "safe" doses differ for two reasons. One is that effects of low dosages are hard to observe. In itself, this absence of obvious effects seems reassuring. On the other hand, it leaves ample room for theorizing and even for guessing.

The second reason is the emotional aspect of the question. Contrary to widespread opinion, scientific judgement is by no means free of emotional influences.

The effect discussed by Warren A. Brill is due to the circumstance of a strictly localized distribution of energy which will have a lesser effect on massive tissue but a relatively greater effect in a strictly localized sense. The situation is well understood. Analogous situations may occur elsewhere. Researchers in the field are well aware of this.

Since the harmful effects of small radiation doses are hard to establish it is justifiable that the recommended levels of "maximum concentrations" should be subject to revision.

The statement that all radiation is "potentially" harmful cannot be contradicted since this could only be based on a complete knowledge of these biological effects. One should remember, however, that evidence of beneficial effects have also been presented. (See the answer to question No. 7.)

I would agree that, in the balance, harmful effects probably predominate. At the same time it is necessary, in my opinion, to approach the problem with considerable doubt, allowing for the possibilities of greater dangers but also for the possibilities of compensating benefits.

It is my opinion that "Permissible Doses" have been set at conservative levels. Therefore one can argue that protective action is required only if "Permissible Doses" are exceeded by a considerable factor.

It may be reasonable to make protective action available to individuals as soon as the "Permissible" body-burden is exceeded. At the same time, one should explain to the affected individuals how slight the chances are that harm will come from the excess of radionuclides. If I were found with 10 times the "acceptable" body-burden I would certainly not go to the inconvenience of subjecting myself to the protective action. Because of the importance of the question of safe doses I have attached on separate sheets a discussion concerning "permissible levels".

13) I believe that "acceptable" limits have been exceeded in the past, may be exceeded at present and will be exceeded in the future. The number of cases where this occurs is small and the total number of people at risk is small.

I believe that the expectation of 16,000 cancer cases per year (an impression which may be left by the statements of Gofman and Tamplin) is not a proper description of the prevailing conditions. One should keep in mind the small percentage of people who are actually exposed to a "maximum acceptable" radiation. Furthermore, one must take into account the greater, but still relatively small, number of people who are exposed to a fraction of this radiation. Even using the figures of Gofman and Tamplin

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for the cancerogenic effects, the actual additional cancer incidence due to localized effects of radiation releases is at present probably less than one per year in the United States.

Concerning the totality of waste released into the environment, special cases could occur where action has to be taken due to truly widespread dissemination. One known example is krypton-85 (with an $11\frac{1}{2}$ year half-life) and tritium (with a 12.3 year half-life) released in the reprocessing of fuel elements. At present this release is negligible. With general acceptance of nuclear power production the release could become more substantial. The question is not an urgent one but if and when it arises the distribution of the radioactivity will be worldwide, rather than nationwide. Actually, remedial measures in this case are feasible.

14) A paper entitled "A Criticism of the Sternglass Article on Fetal and Infant Mortality" gives an answer to this question. A copy of this paper is attached. (It is noted that one of the authors is Tamplin.) While there have been many varied criticisms of Sternglass' thesis, I have selected this particular paper because it demonstrates clearly the difficulty of validating conclusions based on statistics. In many cases the fallacious nature of Sternglass' handling of data is explicitly demonstrated.

It is hard for me to see how a man like Sternglass, who claims to be a scientist, can fail to respond to arguments contained in this paper and still maintain that his case has scientific merit.

15) There is no doubt that natural radiation causes some genetic damage and gives rise to some fetal deaths. No precise numbers can be given.

It is also clear that mutations, due to natural radiation or any other cause, have a positive biological function. Without mutations neither evolution nor adaptation would be possible. Since our environment has changed and is continuing to change at an unprecedented rate, the importance of adaptation cannot be completely deni

In case of genetic (as well as somatic) effects a conservative approach would argue for minimal irradiation. But the general judgement that all mutations are harmful appears to lack clear justification.

16 & 17) Because of the great importance of these questions and because truly expert knowledge is available in the Lawrence Radiation Laboratory, I have asked that detailed answers should be given by an expert on Plowshare--Dr. Glenn C. Werth. These answers will be sent to your office.

I have been taking an interest in Plowshare from the beginning of this project and I may also draw your attention to Chapter 3 of "The Constructive Uses of Nuclear Explosives", pages 80 to 126. This book was written by W. K. Talley, G. H. Higgins, G. W. Johnson and myself. In this chapter the connection between nuclear radiation and Plowshare is discussed.

It may also be permissible for me to make two general remarks.

One is that the development of Plowshare has proceeded in a slow and conservative manner. For this reason it is difficult fully to realize the great potential benefits which could result from the peaceful uses of nuclear explosives. Such benefits are much better understood when actual positive experience is at hand.

The other remark is connected with Alaska. Plowshare could become particularly useful in developing the great resources of your state. Due to the low population density and the climatic conditions, the exploration of the Alaskan resources are hampered by logistic difficulties. It is just under these conditions that Plowshare, whose deployment requires relatively small manpower, can become particularly valuable.

Of course, in no application should human health be endangered. Due to the low population density in Alaska proper safety measures can be enforced without great difficulty.

I hope to have the privilege of talking to you about these important problems when the improvement of my own health will permit me to do so.

18) An old, basic and unshaken fact concerning radioactivity is: it cannot be turned off. No research effort should be wasted on this hopeless enterprise.

What can be done is to remove some radioactivities from the human body after they have been deposited. In many cases this is possible. In some instances, for example in the case of tritium, it can be done without too much difficulty.

19) The krypton and tritium released by a light water reactor is a small fraction of the krypton and tritium release which occurs during the reprocessing of the fuel elements. As I have mentioned in my answer to question No. 13, it may well become important to find the proper methods to limit the release of these materials during reprocessing. In case of krypton-85, containment seems feasible. In the case of tritium, dilution in ample water supplies such as ocean water may have to be recommended. In both cases present contaminations are small and there is time for a thorough consideration.

Leakage from the reactors occurs only due to imperfection of fuel elements. Fabrication of better and more durable fuel elements would certainly be desirable.

To my knowledge, practically no carbon 14 is contained in fossil fuels and discharge of carbon 14 from coal burners need, therefore, not be considered. Thorium and radium is released in small amounts and it has been claimed that radioactive contamination from these is comparable to radioactive contamination from nuclear reactors. I am not in a position to prove or disprove this claim. I know, however, that the radioactive release from coal burners and the radioactive release from nuclear reactors is low. As mentioned earlier, the release of chemical poisons, including sulphur oxides from coal burners and oil burners constitute a much greater hazard.

The percentage difference of fission products generated per kilowatt of heat is quite small when breeder reactors and light water reactors are compared. Substantial differences may arise in the release of the radioactivity from the reactor. It is difficult to judge what this difference will be and whether in this respect breeder reactors or light water reactors are better, prior to a detailed engineering design and a long-period of try-out of breeder reactors.

The number of curies per kilowat at the time of reprocessing will be similar for breeder reactors and light water reactors. Some differences will occur due to the different total neutron bombardment and to the different length of residence of fuel elements in the various kinds of reactors.

It is true that due to the large quantities of plutonium contained in present designs for fast breeder reactors, additional hazards arise. Still further hazards will be encountered for a variety of reasons. These questions seem to me of great importance. All of them are connected, however, with the extremely small probability of a big and catastrophic malfunction. They are not connected with small, steady discharges from reactors. The question is, therefore, not that of pollution control, but rather that of proper safety measures. These questions require a thorough familiarity with the design of nuclear reactors. Since I have been Chairman of the Reactor Safeguard Committee for several years I am familiar with these problems. Considerable differences of opinion do exist concerning the safety of fast breeder reactors. In this particular case I happen to feel that great caution is necessary. It is, however, impossible to discuss this question in a responsible way without going into lengthy, technical arguments.

It is true that significant progress has been made recently in Russia on controlled fusion. It is also true that British scientists have confirmed this progress. It remains, however, uncertain whether and how soon economical controlled fusion will become available. I would like to see research efforts more strongly supported in the United States.

If and when fusion power will become available I expect that this power source will be even safer than present nuclear reactors. On the other hand, such reactors will almost certainly consume and also produce very much greater amounts of tritium than the present fission reactors. The complete containment of these big amounts of tritium will become a problem. One cannot predict the technological development that will have occurred 10, 20 or 30 years hence, when these fusion reactors may become important. The radiation hazard from tritium will depend on the state of technology at a future date and cannot be evaluated at present in a meaningful manner.

WHAT SHALL BE DONE ABOUT THE "MAXIMUM PERMISSIBLE DOSE"?

At the present time the "Maximum Permissible Dose" established by the Guidelines of the National Radiation Council happens to coincide with the national average of radiation exposures which is 0.17 rem/year. This average is due to natural background radiation (0.1/rem/year) and needed diagnostic x rays (0.07 rem/year). Recently it has been proposed that the "Permissible Dose" be lowered at least to 0.017 rem/year.

In the following, arguments will be given for maintaining the present standards. Suggestions are added concerning needed research and better procedures of enforcement.

The present guidelines for "Permissible Doses" should not be lowered for the following reasons:

1) On the basis of common sense the present guidelines are safe.

The main reason for this statement is that the guideline coincides with the average exposure due to causes other than atomic energy developments. This exposure has existed for a long period and furnishes a strong link with experience.

It is generally recognized that the danger to an individual is small if 0.17 rem/year is added to the existing average of 0.17 rem/year. The fact that the chance of damage is so small makes it most difficult to find and to prove damage at these low levels of irradiation.

The opposing argument is that exposure of millions of people may result in numerous cases of damage, even though the probability for any individual is small. This argument must be recognized. At the same time, one should remember that the best evidence we possess is the fact that radiation backgrounds, which vary with location, have not given rise to catastrophic or even to clearly demonstrable effects. Thus, worldwide average irradiation is a valuable source of information concerning the effects, or rather the absence of the noticeable effects, of low-level exposures. It is difficult to perform experiments which have validity similar to this source of information.

For the sake of comparison one may raise the question what would happen if all pollutants, such as stack-discharges and automobile exhausts would be limited to amounts equal to natural background. In that case automobiles of the present type would be eliminated and most of our industries would be shut down. If such regulations were to be enforced only hydroelectric plants, nuclear plants and installations driven by these plants would survive.

The comparison is, of course, unfair. Many substances released into our environment are not found in any appreciable amounts in the natural state. Furthermore, in case of chemical pollutants it is extremely hard to demonstrate that the released material is harmful or that it is completely safe.

In case of radioactive releases, we are in a more fortunate position. We know that all kinds of hard radiation delivered to the living cell has the same kind of an effect. Moderate differences do occur between x rays, β-rays, α-rays, neutrons, and cosmic rays. But drastic differences and consequent surprises are ruled out by the uniform nature in which such radiations affect chemical and biochemical substances.

It is, of course, true that different cells and tissues have widely different sensitivities to hard radiation. Therefore, the radiation guide must be applied with care. In general, one may argue that no human organ should receive more additional radiation than is delivered to that organ by the original average radiation. Thus, no organ should be exposed to more than corresponds to twice the average radiation. This is, in general, how the present radiation guide is applied.

Finally, one should note that many radioactivities, in particular a great fraction of the most common β-activities, are easily discovered and measured. This facilitates monitoring. It also raises public awareness. In case any exaggerated claim is made about radioactive hazards this awareness can give rise to unnecessary alarm. In view of all these circumstances it is wise to base guidelines on old and established averages.

2) Lowering the "Permissible Dose" to a .017 rem/year would hardly save any lives. On the other hand, such an action would result in a loss of considerable benefits and would also give rise to needless complications.

If one applies an estimate of radiogenetic leukemia cases, if one assumes that all cancerogenesis by radiation behaves like leukemia, and if one further assumes that the whole United States population is exposed to the "Maximum Permissible Dose", one obtains by straight multiplication that in the long run more than 16,000 additional cancer cases per year should be expected.

Some doubts exist about all the assumptions which have been mentioned. But the weakest point in this line of argumentation is the assumption that, indeed, all of our population should be exposed to the "Maximum Permissible Dose". Enforcement did proceed and will continue to proceed in practice along such lines that even exposure of quite limited groups of people to more than the "Maximum Permissible Dose" becomes quite unlikely. The result is that doses less than the "Maximum Permissible Dose" are also delivered on relatively rare occasions, particularly since everybody applies considerable safety factors. If actual exposures due to

local releases from reactors or Plowshare explosions are taken into account, one finds on the basis of the remaining conservative assumptions that not more than one additional cancer case per year within the United States should be expected in the long run.

A somewhat greater number of cases might conceivably occur due to the widespread distribution of materials released from reprocessing plants. However, these gaseous products will show great local concentrations near the reprocessing plants and thus the "Maximum Permissible Dose" as applied to the neighborhood of the reprocessing plant will again introduce effective controls. I did not intend to undertake the arduous and uncertain task of evaluating actual damages. The intent of the above figures is merely to indicate how grossly one would be misled if one would take the 16,000 additional cancer cases per year as an effective estimate of what does occur or is likely to occur.

Procedures exist in many cases by which radioactive body-burden can be removed if this body burden should exceed the "Maximum Permissible Dose". Thus occasional exposure of people to excessive radiation can be counteracted and the relatively small hazard to a limited number of people need not be incurred. All of this can and should proceed under the present guidelines.

One case where a "Permissible Dose" of .017 rem/year may lead to substantial complications would be in the international field. Release of tritium and radio-krypton from reprocessing plants may lead in the future to radiation in excess of .017 rem/year. I believe that this can be avoided but as yet methods have not been worked out and it is not possible at the present time to give conclusive statements concerning the necessary costs.

Of special interest in this case is that the radionuclides just mentioned may be distributed on a worldwide scale. While the United States is at present in the leading position in production of nuclear energy and while I consider it likely that we can afford the cost to avoid the uncontrolled release of tritium and krypton from reprocessing plants, I find it hard to predict what will happen in many other countries which will need and demand nuclear energy, and which may have to apply more stringent economies. Guidelines which we introduce will have to be agreed upon by the international community. If we should attempt to take a strict attitude which will permit averages of exposures to radioactivity to rise by no more than a small percentage, it may turn out to be difficult to impose such limitations outside the borders of the United States.

It might appear to be wiser to make our laws more liberal and to make sure that these laws are applied and followed within the United States in an effective manner.

In this way we can accomplish by example what might otherwise be difficult to enforce.

One should pay particular attention to the benefits which result from the application of nuclear energy and to the elimination of some of these benefits if the radiation guide should become too rigorous. Substitution of nuclear plants for electric generators which burn fossil fuel will decrease air pollution. This latter danger to health is great. It is known that during a sustained inversion in the area of New York City the number of deaths in New York City hospitals increase by several hundred. It is possible to use cleaner fossil fuels but this runs into economic and political difficulties. One should give much higher priority to the reduction of the use of sulphur-containing fuels than to the further reduction of radioactive release. Alternatives which would permit to lower the release of sulphur oxides should be clearly spelled out.

A second benefit which might suffer unnecessarily by strict regulations is the Plowshare project. Due to exceedingly great caution, the development of that project has been slow. We have to rely on plans and guesses concerning possible benefits.

In general terms it can be said that the benefits would accrue in transportation and in mining. The ultimate advantages could be greater than those which one can derive from nuclear reactors.

One potential application of Plowshare is specifically relevant to pollution abatement. With the help of Plowshare one can create safe storage space at great depths for radioactive and chemical wastes. These contaminants would be effectively eliminated from the biosphere.

3) A drastic reduction of the "Permissible Dose" has been proposed by Gofman and Tamplin to the Sub-Committee on Air and Water Pollution in the following words: "We shall present to you hard evidence that leads us to recommend that this be reduced now to 0.017 Rads or even less. And we shall present to you the estimated disastrous consequences to the health of the public if this recommendation receives less than immediate, serious attention."

The disastrous consequences mentioned here consist of the additional 16,000 cancer cases per year which have been discussed and shown to be inapplicable under the preceding discussion. It is also to be noted that the statements of Gofman and Tamplin are not based on hard evidence as claimed.

The statements of Gofman and Tamplin are actually based on two assumptions. One is that the probability of damage is proportional to the amount of irradiation (assumption of linearity and absence of a threshhold). The other is that continuously delivered dosage has the same effect as rapidly delivered dosage.

There is only one example where to my knowledge proportionality between dosage and its effects has been supported by consistent observations. This is the case of mutations caused by irradiating spermatozoa, that is, mature male sex cells which consist of a cell nucleus and a propulsive mechanism but no cell body. In all other cells connected with genetic effects (spermatogonia and the female oocytes) in which a substantive cell body is present, repair mechanisms seem to exist. This has been demonstrated by the work of W. L. Russell and his co-workers in Oak Ridge during the past two decades. In cancerogenesis on which the argument for reducing the "Permissible Dose" is based, a cell body is present. Therefore, one can argue against the basic assumptions which have been used at least as easily as one can argue for them. Actually, most of the observations on cancer production are connected with sudden irradiations at much higher levels than corresponds to present "Permissible Dosages". Under the conditions of great and sudden irradiation the protective or repair mechanisms afforded by cell bodies are known to be less effective than is the case for protracted irradiation at a low level. Therefore, the assumptions made in connection with cancerogenesis are probably pessimistic and the evidence cannot be considered hard in a proper scientific sense.

In order to increase both knowledge and safety, and in order to find practical ways in which to enforce guidelines, and avoid unnecessary loss of benefits, the following suggestions may be made:

A. Careful statistical studies should be carried out of the effects of excess radiations where ever they exist. Colorado and the Monazite-rich regions of Kerala and Brazil are examples. Such studies will be difficult. Not to attempt them would be a mistake.

B. Added attention should be given to the various processes by which radioactivities can be concentrated in nature, in the biosphere, and particularly in the human body. Such studies are underway and they should be much more strongly supported. It is by such studies that one can avoid surprises and foresee the most practical methods by which excessive amounts of radiation can be prevented.

C. Expressions such as "Maximum Permissible Dose" should be avoided. Instead it would be reasonable to compare the effects of all radioactive releases with the effects of average radiation exposures. (Apart from the use of the words, this corresponds to present practice.)

When the effect of released radiation reaches at any instance the average radiation (that is, when the effects of the United States average is doubled) in any human organ, or when there is enough fallout to threaten such a concentration in a human organ, protective measures should be taken at the expense of the parties responsible for the radioactive contamination. These protective measures may consist in the removal of some radioactivity from the affected people. In case of tritium contamination, methods for doing this are available. In case of strontium or iodine there are methods to accelerate elimination. With more research and development these methods can probably be improved. In other cases contaminated materials could be removed from the food chain. These protective measures shall proceed promptly whenever the affected people request it.

It should be realized that at present protective measures are only partially effective. In the important case of tritium they are quite effective.

By making them available one can greatly reduce needless worry. Thus, in the long run one can hope to hold actual damage to a minimum even in the few cases where releases exceeding the national average have taken place. In this way it can be made clear that the result of inadvertent release will become primarily an inconvenience to the affected people. It is improper to concentrate on the frightening aspects of improbable fatalities when there are good prospects that methods for preventing such fatalities can be developed.

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